

Chapter 10

Lecture Outline*

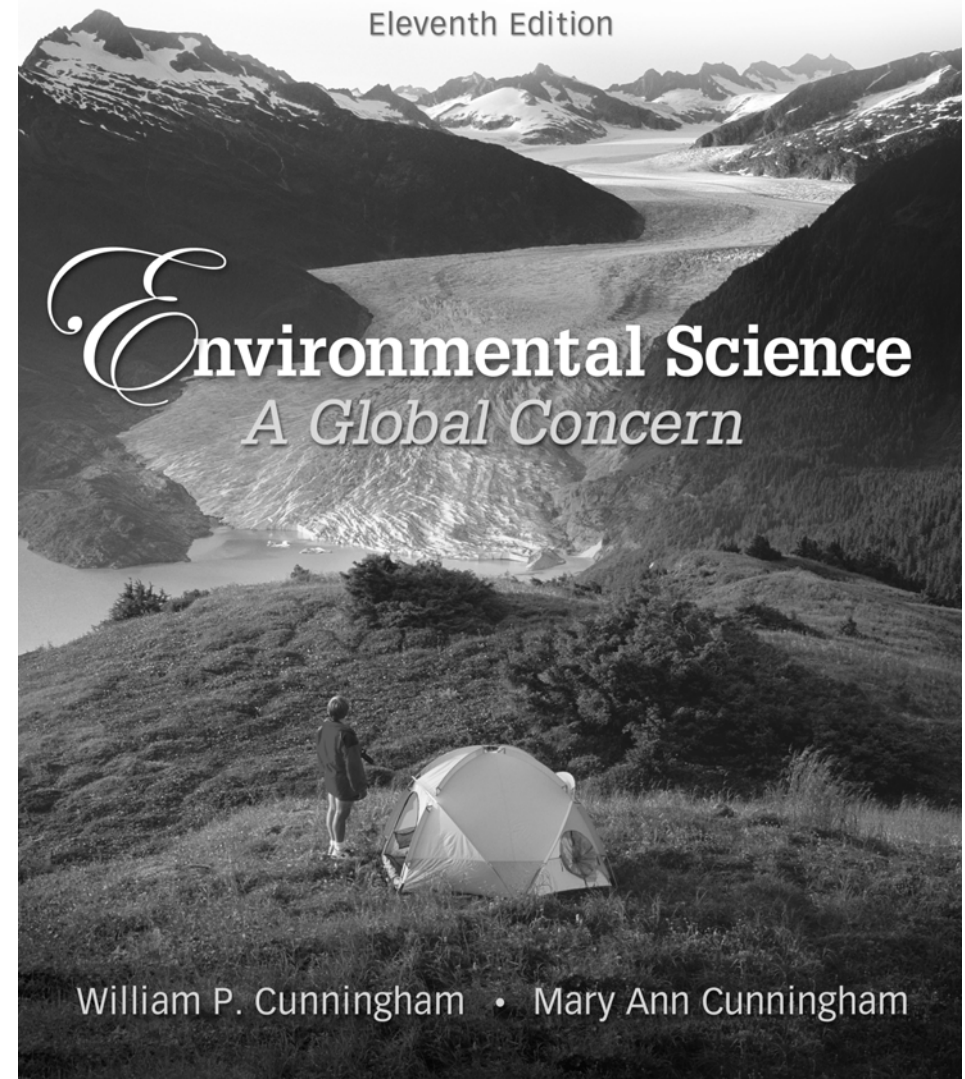
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Farming: Conventional and Sustainable Practices

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Outline

- Resources for Agriculture
- Soil Characteristics
- Soil Ecosystems
- Soil Erosion and Desertification
- Fertilizer and Energy in Farming
- Pests and Pesticide Usage
- Organic and Sustainable Agriculture
- Soil Conservation
- Environmental Impact of Consumers

Resources for Agriculture

- Agriculture has dramatically changed our environment, altering patterns of vegetation soils and water resources worldwide.
- Some agricultural lands have been depleted in just a few decades while others have been sustained for centuries.
- In this lecture, we will examine what farming practices degrade agricultural resources and what farming practices help to restore and rebuilt these resources.

Soils are Complex Ecosystems

- Soil is a renewable resource that develops gradually through the weathering of rocks and the accumulation of organic material.
- The accumulation of topsoil is a very slow process. Under the best circumstances it accumulates at a rate of about 1 mm/year.
- With careful management, soil can be replenished and renewed indefinitely.
- Most farming techniques deplete soil through erosion and removal of organic material.
- Severe erosion rates can exceed 25 mm soil /year.

6 Components of Soil

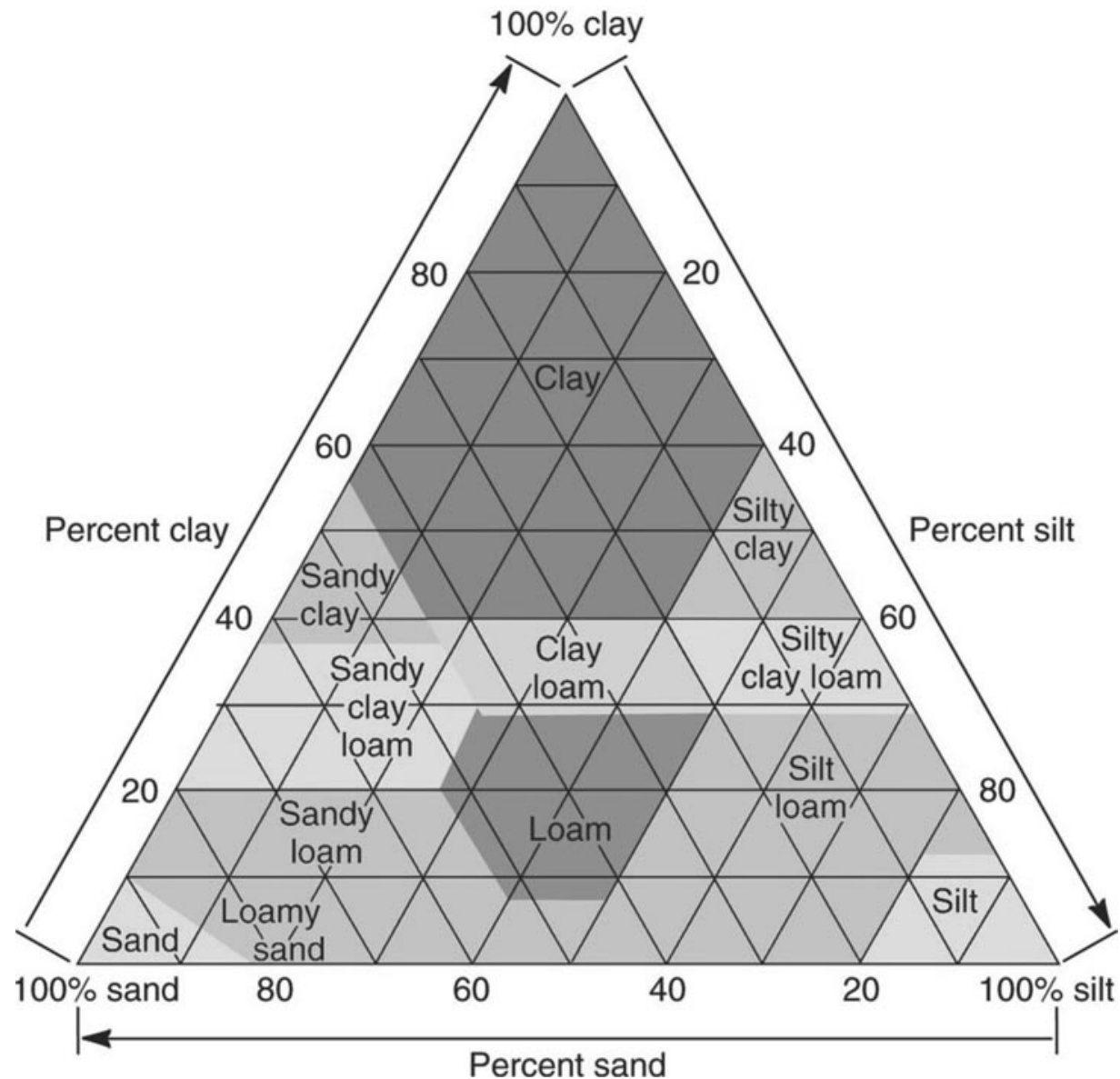
- Soil is a marvelous, complex substance; an entire ecosystem that is hidden to most of us. In general it has 6 components:
 - ❖ Sand and gravel
 - ❖ Silt and clay
 - ❖ Dead organic material
 - ❖ Soil fauna and flora
 - ❖ Water
 - ❖ Air

Variation in Soil Composition

- Variation in the 6 components of soil can produce and almost infinite variety of soil types.
- Soil texture, the amount of sand, silt and clay in the soil, is the most important characteristics of soils.
- Loam soils are considered best for agriculture because they are a mixture of sand, silt and clay.
- Brazilian tropical soils are deeply weathered red clays which have little organic material. They hold few nutrients and water .
- The rich, black soils of the Midwestern US are rich in nutrients and organic material and contain a mixture of sand, silt and clay to hold moisture well

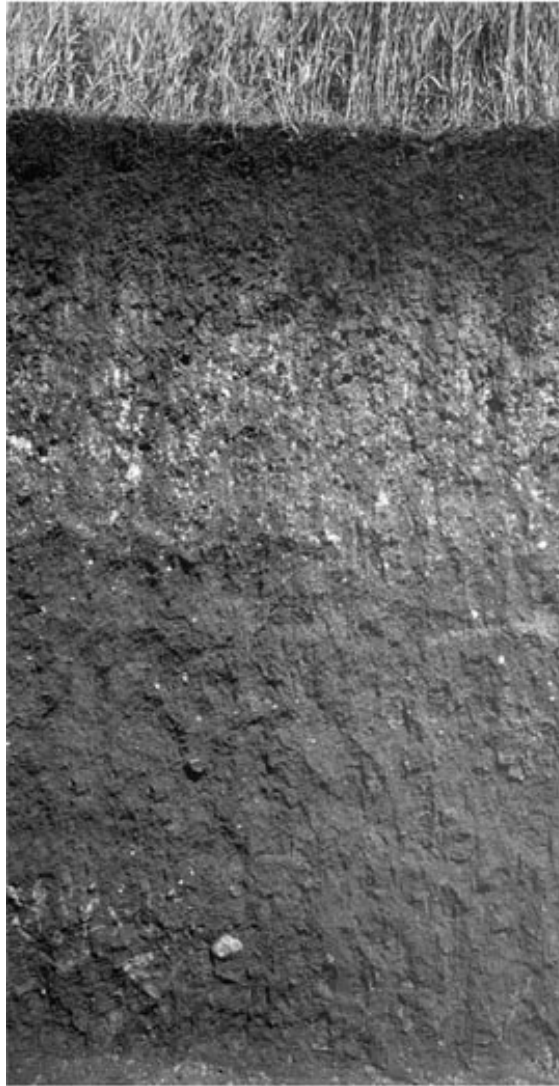
Soil Texture Pyramid

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Grassland vs. Tropical Rainforest Soils

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(a)



(b)

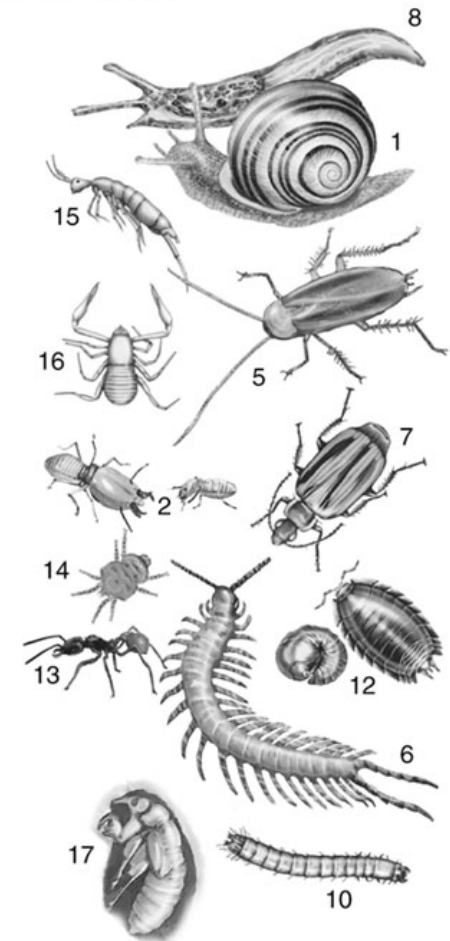
Courtesy USDA/NSCC

Soil Fauna Determine Fertility

- Soil bacteria, algae and fungi decompose leaf litter making recycled nutrients available to plants.
- A single gram of soil can contain hundreds of soil bacteria and 20 meters of tiny fungal strands.
- Tiny worms and nematodes process organic material and create air spaces as they burrow.
- Larger insects, spiders and mites loosen and aerate the soil as well.
- Micorrhizal symbiosis, an association between plant roots and certain fungi. The plant feeds the fungus and the fungus provides water and inorganic nutrients to the plant enhancing growth.

Soil Ecosystems

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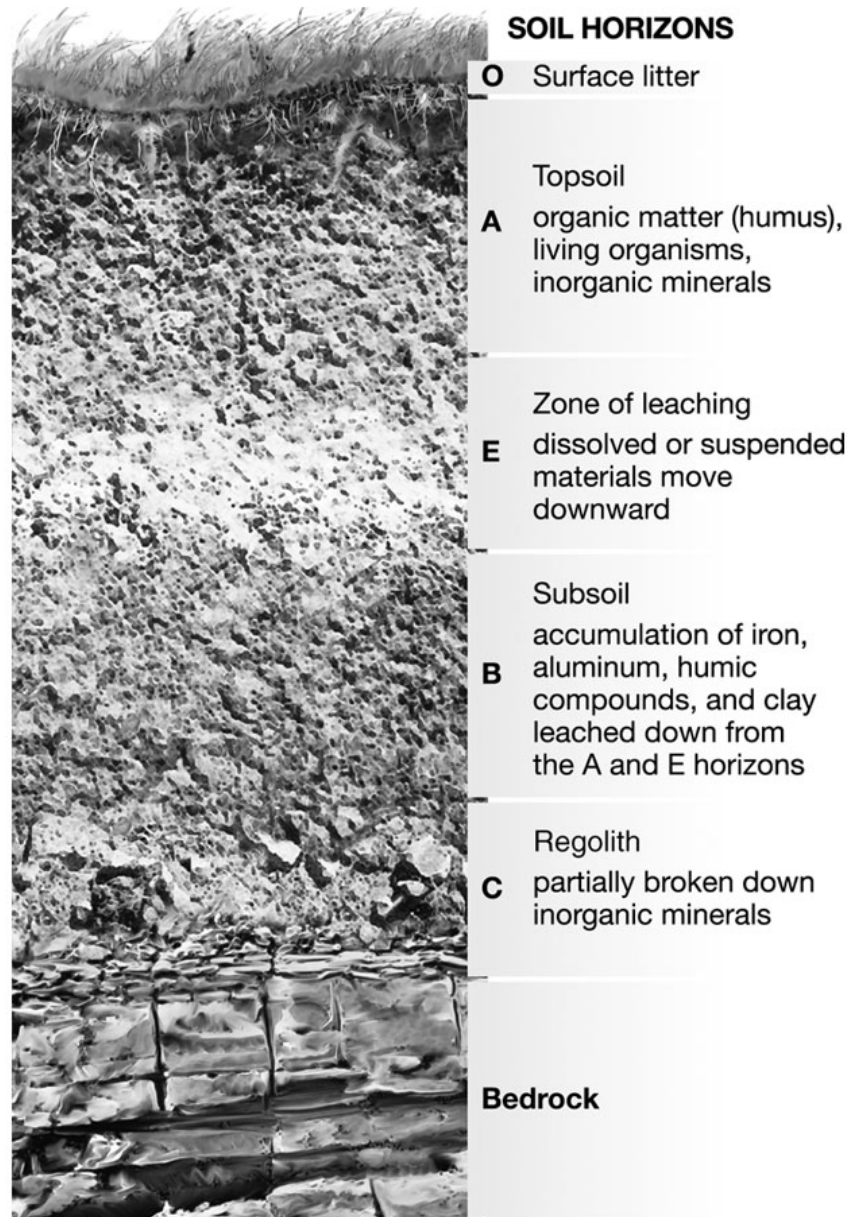


Soils are Layered

- Soils are stratified into horizontal layers called soil horizons.
 - ❖ Horizons taken together make up soil profile.
 - O Horizon (Organic layer)
 - Leaf litter, most soil organisms and partially decomposed organisms
 - A Horizon (Surface soil)
 - Mineral particles mixed with organic material

Soil Profiles

- E Horizon (washed out)
 - Depleted of soluble nutrients
- B Horizon (Subsoil)
 - Often dense texture from accumulating nutrients
- C Horizon or regolith (Parent Material)
 - Weathered rock fragments with little organic material



Food Comes from the A Horizon

- Because soils are so important to our survival, we identify soils largely in terms of the thickness and composition of their upper layers.
- In the farm belt, the dominant soils are mollisols. These soils have a thick, organic-rich A-Horizon which developed when this land was covered by prairie grasslands.
- Alfisols are another soil type important for farming. These soils developed in deciduous forests and have a thinner A-Horizon and less organic material.
- Mollisols and Alfisols dominate most of the soils of farming country in the US.

Ways We Use and Abuse Soil

- Approximately 12.5% of the earth's land area is currently in agricultural production.
 - ❖ Up to four times as much could potentially be converted to agricultural use.
 - However, much of this additional land suffers from constraints such as steep slope, soggy soil, too cold, too dry or too much salt.
- The ecological effects of converting these lands to agriculture include loss of biodiversity, clean water and other ecological services provided by these grasslands or forests.

Arable Land Unevenly Distributed

- Arable land is unevenly distributed across the world. The best farming occurs in moderate climates with thick fertile soils.
- North America and Europe are particularly well suited to growing while some other parts of the world lack suitable soil, topography and water.
- Gains in agricultural production have come from increased fertilization, pesticides and irrigation rather than more land.
- As productivity in North America and Europe has increased in recent years some marginal lands have been retired and less land is now cultivated than in the past.

Distribution of US Cropland

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USDA Natural Resource Conservation Service

Soil Losses Cut Farm Production

- Every year, about 3 million hectares of cropland worldwide are made unusable by erosion and another 4 million hectares are converted to non-agricultural uses.
- Most land degradation happens slowly as soil washes or blows away, salts accumulate and organic matter is lost.
- As a consequence of these processes as well as increases in world population, arable lands worldwide have shrunk from 0.38 ha/person in 1970 to 0.23 ha/person in 2000.

Water Moves Soil in Various Ways

- A farm can lose up to 20 metric tons of soil/hectare/year from one of these processes:
 - ❖ Sheet Erosion - thin layer of surface removed
 - ❖ Rill Erosion - small rivulets of running water gather together and cut small channels
 - ❖ Gully Erosion - rills enlarge to form bigger channels too large to be removed by normal tillage
 - ❖ Streambank Erosion - washing away of soil from banks of streams and rivers

Wind Moves Soil Also

- Wind can equal or exceed water as an erosive force, especially in a dry climate and on flat land.
- Desertification - conversion of productive land to desert
 - ❖ Intensive farming practices responsible for erosion:
 - Row crops leave soil exposed.
 - Weed free-fields
 - Removal of windbreaks
 - No crop-rotation or resting periods for fields
 - Continued monoculture cropping can increase soil loss tenfold.

Deserts are Spreading

- Desertification of productive lands threatens 1/3 of the earth's surface and over 1 billion people
- Rangelands and pastures are highly susceptible (overgrazing, soil degradation).
- Africa and China are of particular concern.
 - ❖ Rapid population growth and poverty create unsustainable pressures.
 - ❖ Removal of trees for fodder and firewood triggers climate change that spreads desertification.

Desertification

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(a) Sheet and rill erosion

Photo by Lynn Betts, courtesy of USDA
Natural Resources Conservation Service



(b) Gullying

Photo by Jeff Vanuga, courtesy of USDA
Natural Resources Conservation Center



(c) Wind erosion and desertification

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Other Agricultural Resources

- All Plants Need Water to Grow
 - ❖ Agriculture accounts for largest single share of global water use.
 - Much irrigation water lost to seepage and evaporation
 - In some countries, low cost encourages over-use of water.
 - Waterlogging
 - Salinization - mineral salts accumulate in soils; lethal to plants

Plants Need Fertilizer Also

- Lack of nitrogen, potassium, and phosphorus often limits plant growth.
 - ❖ Adding nutrients via fertilizer usually stimulates growth and increases crop yields.
 - 1950 - average of 20 kg/ha fertilizer used
 - 1990 - average of 91 kg/ha fertilizer used
 - ❖ Overuse causes water pollution.
 - ❖ Manure and nitrogen-fixing bacteria are alternative methods of replenishing soil nutrients.
 - ❖ Fertilizer use could increase crops in Africa.

Farming is Energy Intensive

- ❖ Fossil fuel use began with the advent of tractors in the 1920's and increased after WWII with the use of natural gas to produce synthetic fertilizers.
- ❖ In the decades that followed, increased reliance on mechanization has increased the reliance on fossil fuels
- ❖ Today, the U.S. food system consumes 16% of total energy use.
 - Most foods require more energy to produce, process, and transport than we get from eating them. Eating locally grown foods has less environmental impact.

Pests and Pesticides

- Biological Pests – organisms such as insects or fungi that compete with humans to consume agricultural crops.
- Pesticides are chemicals that kill biological pests.
 - ❖ Biocides kill a wide variety of living organisms
 - ❖ Herbicides kill plants
 - ❖ Insecticides kill insects
 - ❖ Fungicides kill fungi
- Synthetically produced pesticides are the most common method of controlling pests in modern agricultural production.

Use of Pest Controls is Not New

- The ancient Sumerians used sulfur to kill insects and mites over 5000 years ago.
- The ancient Chinese used mercury and arsenic to control pests.
- Greeks and Romans used oil, sulfur, ash, lime and other natural materials to protect their livestock and crops from pests.
- Crop rotation, burning of fields and use of biological controls have also were used by a variety of ancient cultures.

Pros and Cons of Modern Pesticides

- The era of synthetic organic pesticides began in 1939 with DDT.
- DDT was inexpensive, stable, easily applied, highly effective
- By the 1960's, evidence showed DDT was concentrating through food chains.
- Carnivorous birds such as eagles suffered egg shell thinning leading to an inability to reproduce.
- In 1962, Rachel Carson warned of the dangers and DDT was banned in the US by the late 1960's
- It is still used in developing countries.

Pros and Cons of Modern Pesticides

- Since the development of DDT, many new synthetic pesticides have been developed.
- Like DDT, many of them have proven to have unintended consequences on non-target species.
- The EPA estimates total pesticide use in the U.S. amounts to about 5.3 billion pounds annually.
 - ❖ Roughly 80% of all conventional pesticides applied in the U.S. are used in agriculture or food storage and shipping.
 - ❖ Home and Garden use account for about 8% of US pesticide use annually.

Worldwide Pesticide Use

- The EPA estimates that worldwide use of conventional pesticides amounts to over 5.7 billion pounds of active ingredients per year.
- 75% of these are used for agriculture.
- 14% is used for home and garden application
- The US accounts for about 60% of world pesticide usage.

Pesticide Types

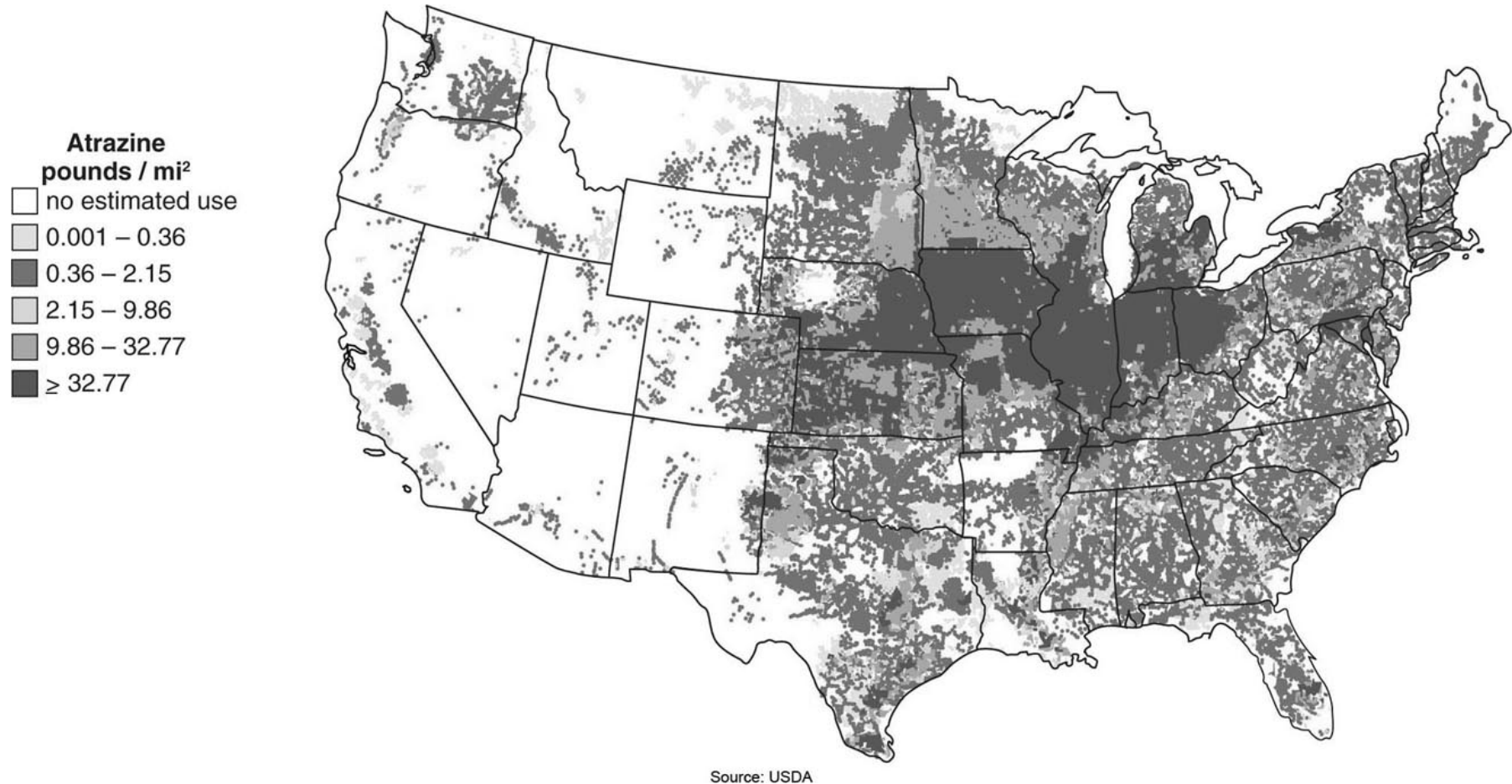
- Organophosphates – most abundantly used synthetic pesticides.
 - ❖ Roundup-most commonly used organophosphate herbicide
 - ❖ Other organophosphates are used as insecticides and inhibit cholinesterase, an enzyme necessary for nervous system function.
 - ❖ Quickly degrade and do not persist.
 - ❖ Dangerous to workers and can be lethal

Pesticide Types

- Chlorinated Hydrocarbons - fast acting and highly toxic to sensitive organisms
 - ❖ Atrazine, Paradichlorobenzene (mothballs) and DDT are examples.
 - ❖ Persistent and concentrate in food chains
- Fumigants-small molecules (ie. Carbon tetrachloride) which are delivered as a gas to penetrate soil or other materials.
 - ❖ Used in fungus control on strawberries or to prevent insect/rodent damage to stored grains.
 - ❖ Extremely dangerous to workers and restricted or banned in some areas.

Map of Atrazine Usage in US

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Pesticide Types

- Inorganic Pesticides-compounds of toxic elements such as mercury or arsenic.
 - ❖ Highly toxic but indestructible and persistent.
 - ❖ Generally act as nerve toxins.
- Natural Organic Pesticides-generally extracted from plants and include such pesticides as nicotine or pyrethrums.
 - ❖ Toxic to insects and may prevent wood decay

Pesticide Types

- Microbial Agents and Biological Controls- living organisms or toxins derived from them that are used in place of pesticides
 - ❖ Bacteria such as *Bacillus thuringiensis* kill beetles.
 - ❖ Parasitic wasps such as *Trichogramma* kill moths.
 - ❖ Ladybugs are used to control aphids

Environmental Effects of Pesticides

- Widespread use of pesticides brings a number of environmental and health risks.
- Non-Target Species
 - ❖ Up to 90% of pesticides never reach intended target and instead kill beneficial organisms.
 - ❖ Honey bees are one such example
- Pest Resurgence
 - ❖ a few resistant pests survive the pesticide and survive to repopulate the area with more resistant pests.
 - ❖ Resistant pests require finding new pesticides

Persistent Organic Pollutants

- Persistent Organic Pollutants (POP's) –are chlorinated hydrocarbons like DDT that are stable, effective, highly soluble and toxic.
 - ❖ They can travel far from the point of dispersal.
 - ❖ Stored in fat and tend to bioaccumulate
 - High levels have been detected in predators at the upper levels of food chains
 - POP's accumulate in polar regions by the “grasshopper effect”; they evaporate from warm regions and condense in cold regions.

Environmental Persistence and Mobility

- Many POP's were banned globally in 2001 when 127 countries signed a treaty.
 - ❖ Use of these chemicals was previously banned or restricted in developed countries, but U.S. companies continued to sell POPs in underdeveloped countries where regulations were lax.
 - Many pesticides then returned to U.S. in agricultural products and migrating wildlife.
- Since the treaty banning POPs, other pesticides have taken their place.

Human Health Problems

- WHO estimates 25 million people suffer acute pesticide poisoning, and 20,000 die each year.
 - ❖ At least 2/3 of these result from occupational hazards in developing countries.
 - ❖ Chronic, or Long-term health effects are difficult to conclusively document, but effects may include:
 - Cancer, Birth defects, Neurological problems, Immune system problems
- A USDA study shows 73% of conventionally grown foods in the US contain residue of at least 1 pesticide and some contain more than 1 pesticide.

Organic and Sustainable Agriculture

- Numerous studies have shown organic, sustainable agriculture is more eco-friendly and leaves soil healthier than intensive, chemical-based monoculture cropping.
 - ❖ Currently, less than 1% of all American farmland is organic but market is growing.
 - ❖ Organic food must be produced without the use of hormones, antibiotics, pesticides, synthetic fertilizers or genetic modification.
 - ❖ Animals must be raised on organic feed, given access to the outdoors, given no steroids or growth hormones and given antibiotics only to treat disease.

Health Hazards of Pesticide Usage

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Photo by Tim McCabe, courtesy of USDA Natural Resources Conservation Service

Organic and Sustainable Agriculture

- Critics are disappointed by limited scope of the definition of organic. They hope to include:
 - ❖ Growing food in harmony with nature
 - ❖ Food distribution based on co-ops, farmer's markets, and local production
 - ❖ Food should be simple, wholesome, nutritious.
At present, processed ingredients are allowed in organic food.
- Some doubt whether organic growers can produce enough to feed everyone.

Organic Produce

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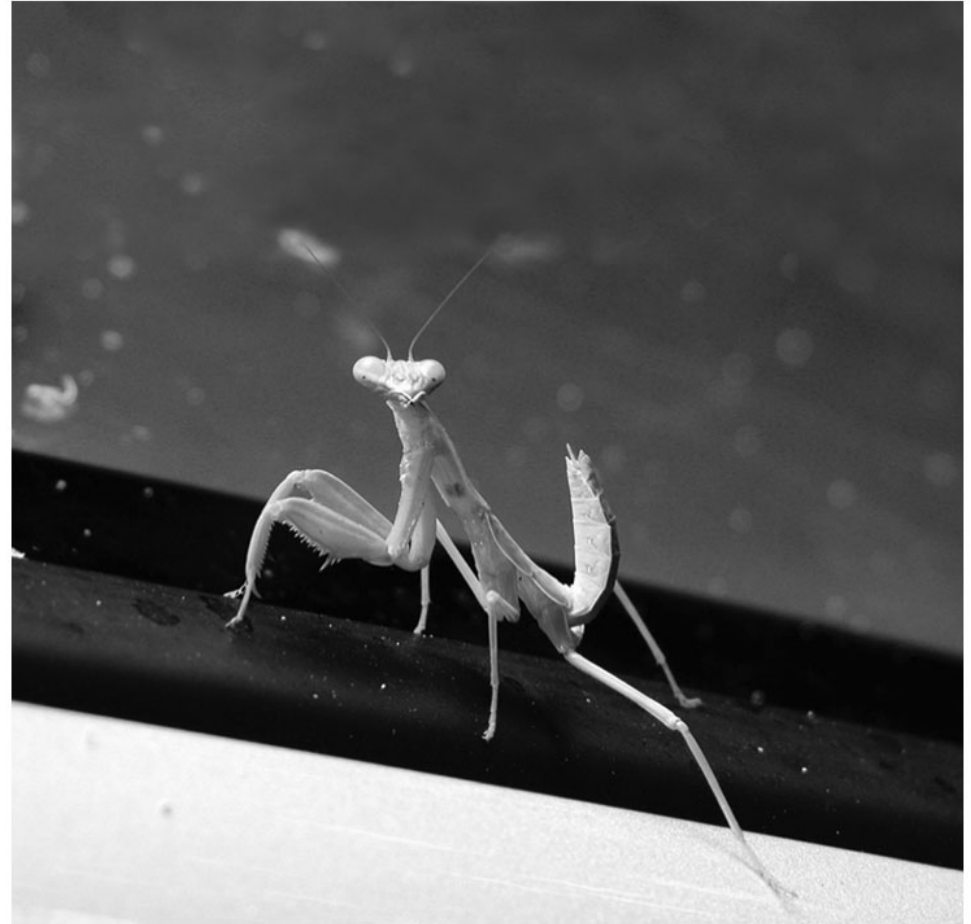
Careful Management Can Reduce Pests

- Behavioral Changes
 - ❖ Crop Rotation
 - ❖ Mechanical Cultivation
 - ❖ Flooding Fields
 - ❖ Habitat Diversification
 - ❖ Growing in Pest-Free Zones
 - ❖ Adjusting Planting Times
 - ❖ Plant Mixed Polycultures
 - ❖ Tillage at the Right Time

Biological Controls

- Predators or pathogens
- Insects that eat weeds
- Plants like the neem tree that make their own pesticides
- Bioengineering
- Release of sterile male insects
- Hormones that disrupt development or attract insects to traps

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IPM Uses a Combination of Techniques

- Integrated Pest Management -is a flexible, ecologically bases strategy that is applied at specific times against specific pests.
 - ❖ Some use of pesticides takes place, but the time, type and method of application are controlled.
 - ❖ Trap crops - small areas are planted before the main crop. These plants mature first and attract the insects, and the trap crop is then destroyed along with the pests.
- IPM is being used successfully all over the world. Cuts pesticide use while maintaining yield.

Crop Vacuum Removes Insect Pests

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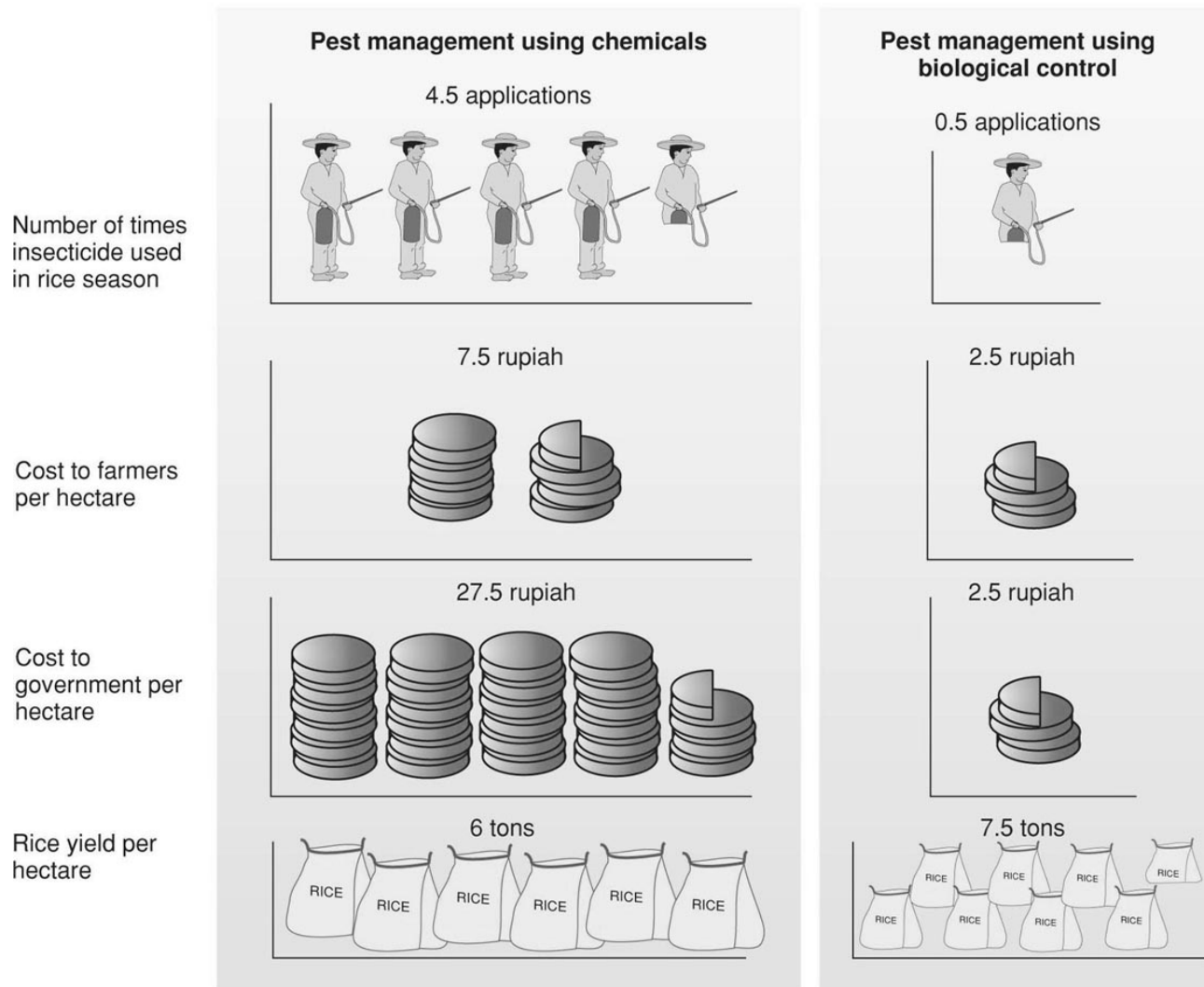


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Alternative Pest Control Strategies

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Alternative Pest Control Strategies



Source: Tolba, et al., World Environment, 1972-1992, p. 307, Chapman & Hall, 1992 United Nations Environment Programme

Soil Conservation

❖ Managing Topography

- Contour Plowing - plowing across slope to slow flow of water
- Strip Farming - planting different crops in alternating strips along land contours
- Terracing - shaping land to create level shelves of earth to hold water and soil
- Plant perennial species.

Contour Plowing

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Photo by Lynn Betts, courtesy of USDA Natural Resources Conservation Service

Terracing

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Ground Cover Protects Soil

- Methods of Providing Ground Cover
 - ❖ Annual row crops cause highest rates of erosion because they leave soil bare for much of the year.
 - Leave crop residue after harvest.
 - Plant cover crops such as clover after harvest.
 - Interplant two different crops in the same field. Harvest one; the other is left to hold the soil. Double harvests are an advantage as well.
 - Mulch

Reduced Tillage Leaves Crop Residue

- Reduced Tillage
 - ❖ Minimum Till - reducing number of times soil is disturbed
 - ❖ Conserv-Till - uses a disc called a coulter to open a furrow just wide enough for seed
 - ❖ No-Till - drilling holes in ground for seed
- Often farmers using conservation tillage depend relatively heavily on pesticides, which is a disadvantage.

Low Input Sustainable Agriculture

- Small scale, low input agriculture
- No synthetic chemicals
- Raising cows on pasture grass rather than grain
- No antibiotics
- Typically produces smaller yield, but production costs are lower and prices are higher so net gain is higher
- Preserves rural culture better than factory farms

Consumers' Play and Important Role

- Adopting a vegetarian or organic diet can reduce environmental impact.
- An even greater impact can be made by becoming a locavore, a person who eats locally grown, seasonal food.
- Join a community supported agriculture program (CSA) in which you make a payment to a local farm in return for weekly deliveries of food.